Tutorial
H-1000-5339-02-A

RENISHAW
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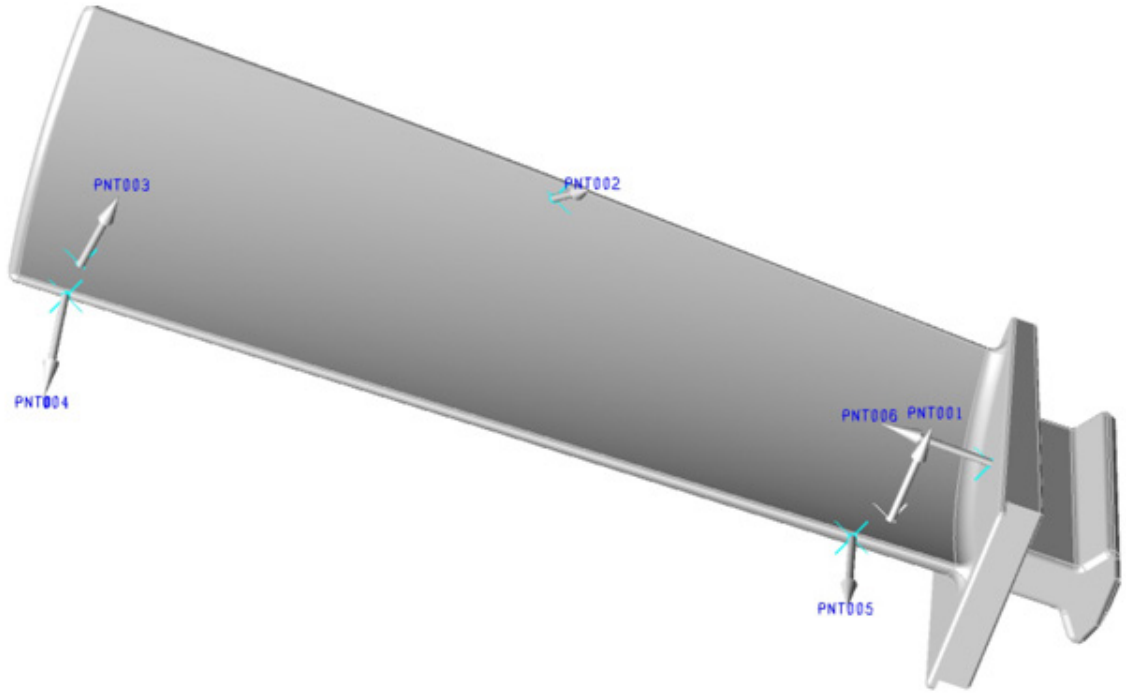
6 point alignment and locate datum



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6 point alignment and locate datum

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1 6 point alignment and locate datum

1.1 Tutorial pre-requisites

- The student should have completed the basic MODUS tutorials
- The student should have completed the ‘Introduction to high level programming’ tutorial

1.2 Tutorial objectives

- Further exposure to part alignment, with a focus on non-prismatic, freeform parts
- Further exposure to the measurement and output of curve features

2 Introduction

On a prismatic part like an engine block, alignment of the part is a simple matter of using standard features like planes, lines and circles. However, on a free form part, such as an airfoil blade or an automotive body panel, there are usually no simple surfaces in which to align the part using a standard 3-2-1 alignment. Fortunately, MODUS has a way to align a free form part using datum locate and iterate functions.

Datum, locate uses measured points against nominal data on the part to adjust the alignment until the part location has the least error possible.

On a free form part, it is impossible to measure the points at the proper location on the first attempt. Since the datum is created after the points are measured, the points move from their nominal position and need to be re-measured to check the quality of the datum. After measuring them again, they will be closer to nominal than the first time they were measured.

This process of measuring, creating a datum and re-measuring is known as an iterative process. When this is done enough times, the points will usually be located within an acceptable error. The acceptable error and number of iterations can be set in the iterate command.

This operation can be performed on any part, including a prismatic part like the Renishaw demo block, but it is intended for freeform parts. Therefore, this tutorial will use an airfoil example.

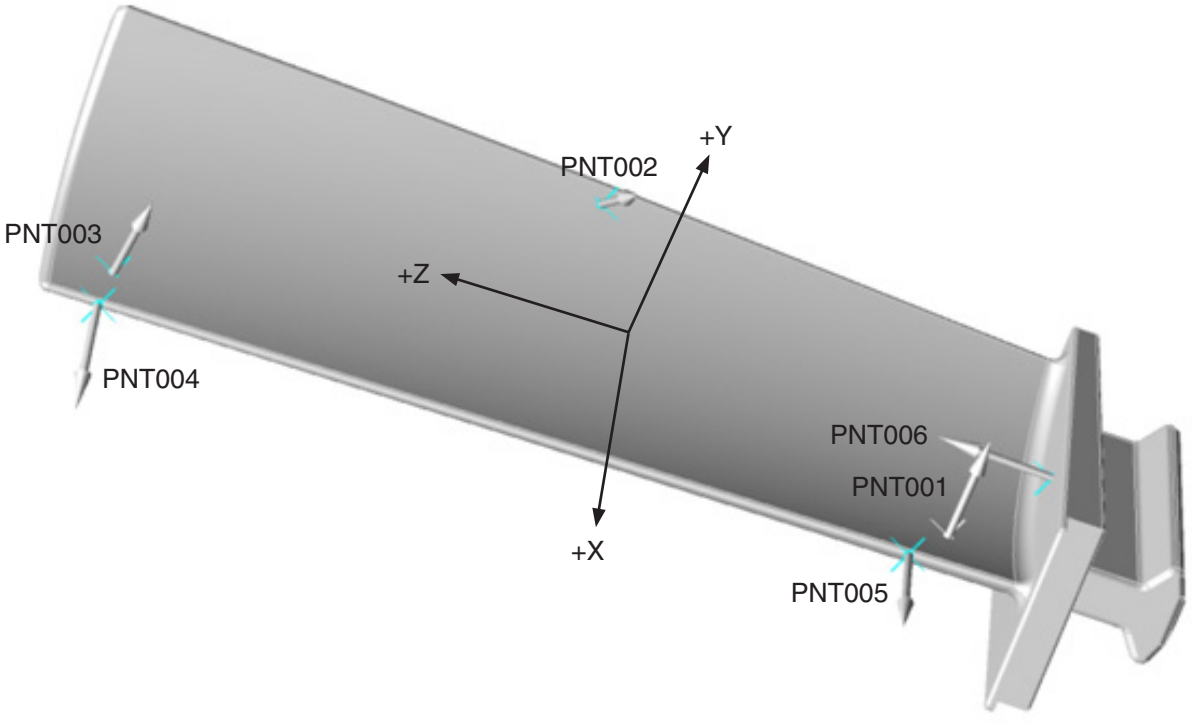
3 Six point locate

Begin a new MODUS program in manual mode and measure six points. The location and directions of the points should be given careful consideration. In some instances, the points will be determined previously and may have datum targets or a point list specified on a drawing, in these cases the nominal data must be entered manually into the grid.

If measuring a CAD model, click ‘Inspect’ then select ‘Multi point’. Now click on the CAD model to define the six points required for the alignment. Click ‘Apply’ and then measure the points selected on the component.

Generally, three of the points should be primarily in one direction, two in a direction that is approximately 90 degrees from the first, and the third point in a direction that is approximately perpendicular to the other two directions.

- PNT001 - PNT003 are mostly in the plus Y direction : Giving a Primary Axis in Y
- PNT004 – 5 are mostly in the plus X direction : Allowing Rotation to be set about the Y Axis
- PNT006 is mostly in the plus Z direction : Setting the final Tertiary point

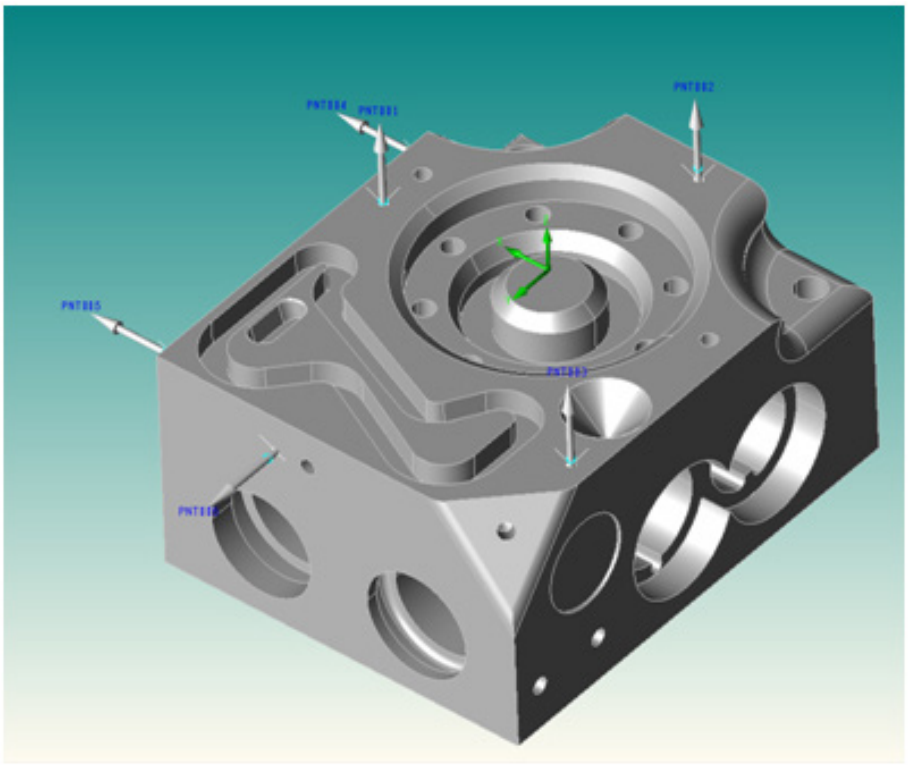


The set of six points must create a valid 3-2-1 alignment. In other words, these points must constrain the six degrees of freedom.

Example code:

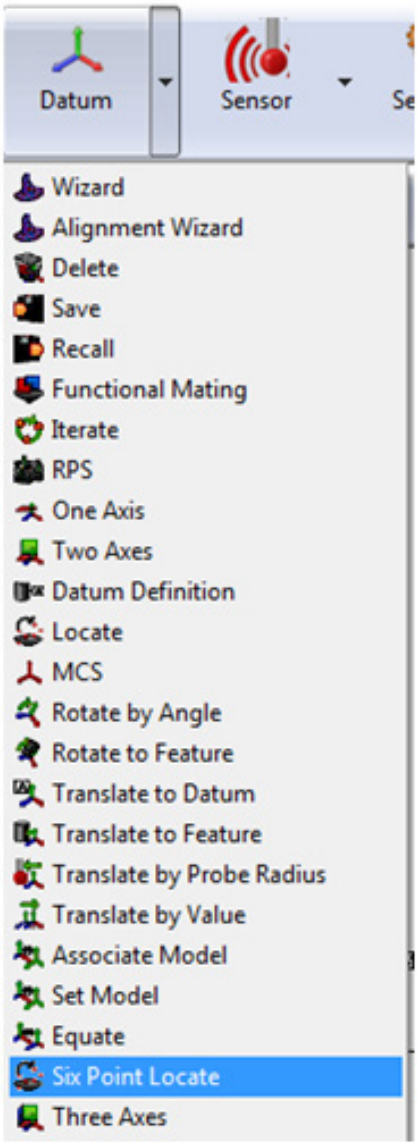
```
MODE/MAN

F(PNT001)=FEAT/POINT,CART,34.586,-11.461,8.962,-0.089,0.994,0.058
MEAS/POINT,F(PNT001),1
ENDMES
F(PNT002)=FEAT/POINT,CART,4.212,-2.73,58.675,0.7,0.714,0.008
MEAS/POINT,F(PNT002),1
ENDMES
F(PNT003)=FEAT/POINT,CART,27.931,-18.891,117.377,0.23,0.969,0.085
MEAS/POINT,F(PNT003),1
ENDMES
F(PNT004)=FEAT/POINT,CART,32.904,-20.543,118.836,0.921,-0.387,0.037
MEAS/POINT,F(PNT004),1
ENDMES
F(PNT005)=FEAT/POINT,CART,41.015,-11.367,14.426,0.996,0.027,0.08
MEAS/POINT,F(PNT005),1
ENDMES
F(PNT006)=FEAT/POINT,CART,26.204,-4.139,-1.875,-0.066,-0.024,0.998
MEAS/POINT,F(PNT006),1
ENDMES
```

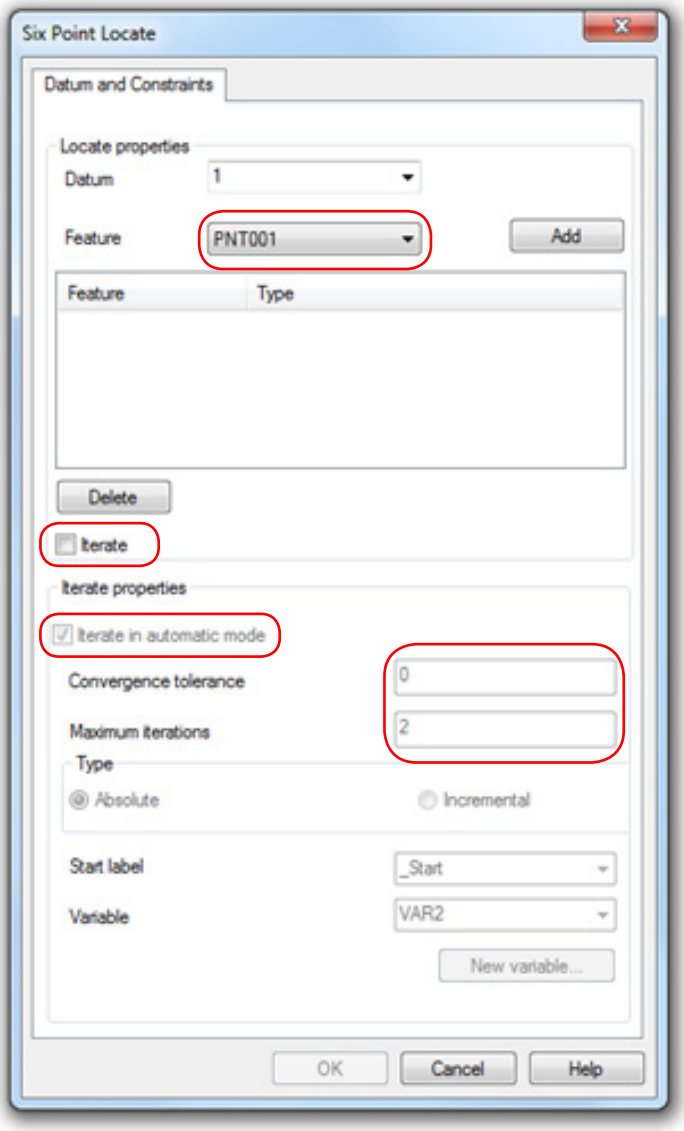
This is very similar to a PLANE-LINE-POINT alignment on a square block. The alignment would not work if the points were all on the top plane, which is why two are on one side that is perpendicular to the top and another point is on a side that is mutually perpendicular to the first two planes. Either of these examples will work when performing a ‘Six point locate’.



Once the points are measured, select ‘Six Point Locate’ from the ‘Datum’ menu.

GUIDANCE NOTE: If ‘Locate’ is selected instead of ‘Six Point Locate’, the user is required to add additional labels and ‘JUMPTO’ statements. ‘Six Point Locate’ adds all required code automatically.





In the ‘Six Point Locate’ prompt, select a point from the drop down list and click ‘Add’. Continue adding points until all points are in the ‘Feature list’.

Click the ‘Iterate’ and ‘Iterate in automatic mode’ checkboxes. This adds a variable, labels, JUMPTO statements, and an iteration statement. Together these cause the program to keep running through the code until the error of each point is within the convergence tolerance, or the maximum number of iterations is complete. Enter the convergence tolerance and the maximum number of iterations. These control how close the alignment will be and how many attempts will be made. The defaults for everything else are acceptable.

The following is added to the MODUS program automatically:

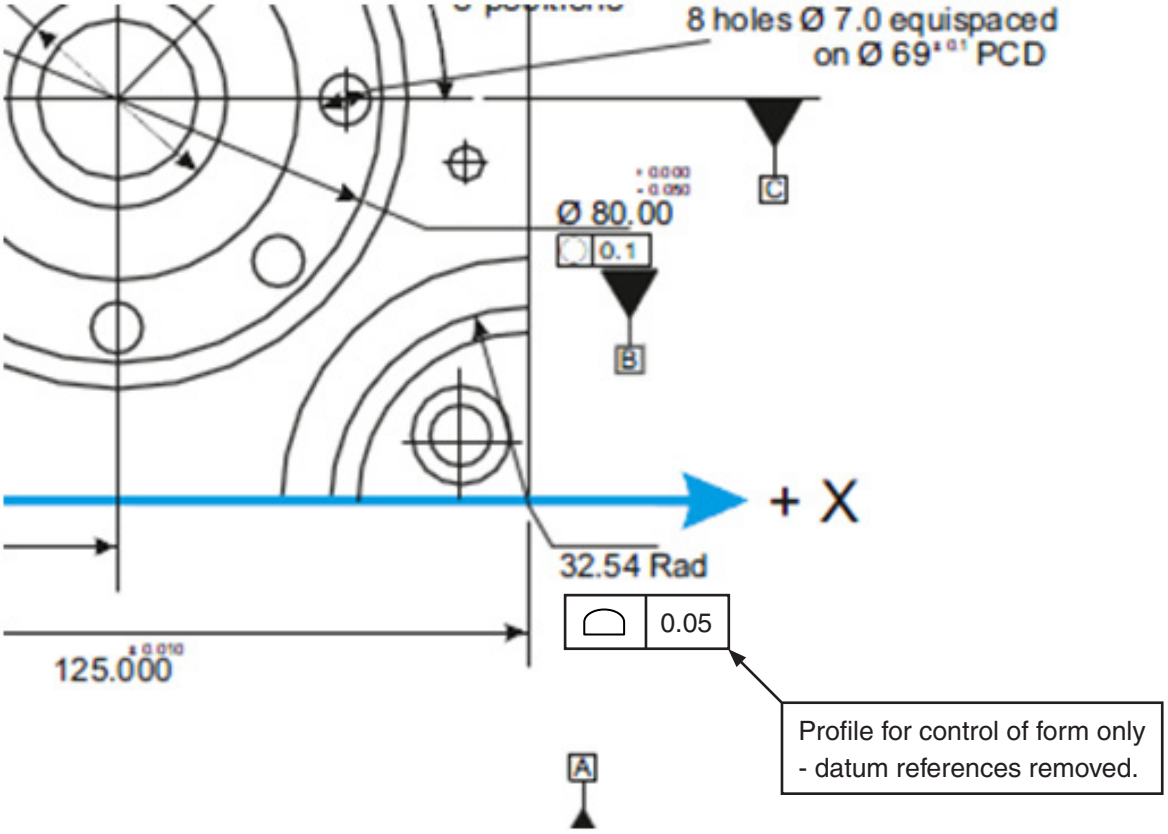
- A ‘Start’ label is added just before the first point - Execution moves to this label after the datum is completed. The six points are measured again and the iteration will be tested again.
- A ‘Fail’ label is added at the end - Execution moves here after the maximum iterations are completed without success. An endfil, additional logic or text statement can be added after the fail label if needed.
- A ‘Pass’ label is added at the end - The remainder of the program should be completed after this label since this indicates a successful alignment has been achieved.
- An Automatic mode command is added if the Iterate in automatic mode checkbox is checked.
- A variable is declared (e.g. VAR2) and an iteration line is added after the last point; this tests the point error (and if the maximum iterations have been exceeded).
    - If the iteration passes, control goes to the next line
    - If the tolerance is exceeded and it has not exceeded the number of iterations, execution jumps to the Do_Datum label
    - If the maximum number of iterations is reached and the tolerance exceeds the limit, execution jumps to the fail label
    - If the tolerance passes, execution jumps to the ‘Pass’ label
- A JUMPTO/(Pass) label is added.
- A Do_Datum label is added.
- A Locate datum is added, which re-aligns the datum.
- A JUMPTO/(Start) is added to run the iteration again.

Example code:

```
(_Start)

---------- Six Points (programmed previously) ---------

$$<SIX_POINT_LOCATE_DATUM>
DECL/LOCAL,DOUBLE,VAR2
MODE/AUTO,PROG,MAN
VAR2=ITERAT/(_Do_Datum),(_
Fail),0.005,ABSL,3,NOM,FA(PNT001),FA(PNT002),FA(PNT003),FA(PNT004),FA(PNT005),FA(PNT006)
JUMPTO/(_Pass)
(_Do_Datum)
D(1)=LOCATE/FA(PNT001),FA(PNT002),FA(PNT003),FA(PNT004),FA(PNT005),FA(PNT006)
JUMPTO/(_Start)
$$<\SIX_POINT_LOCATE_DATUM>
(_Fail)
(_Pass)
```

4 Best fitting a curve

Datum locate can be used to best fit a feature such as a curve. In this example a curve is measured to determine the profile, disregarding position. An arc will be measured as a GCURVE and a best fit will be performed using datum locate.

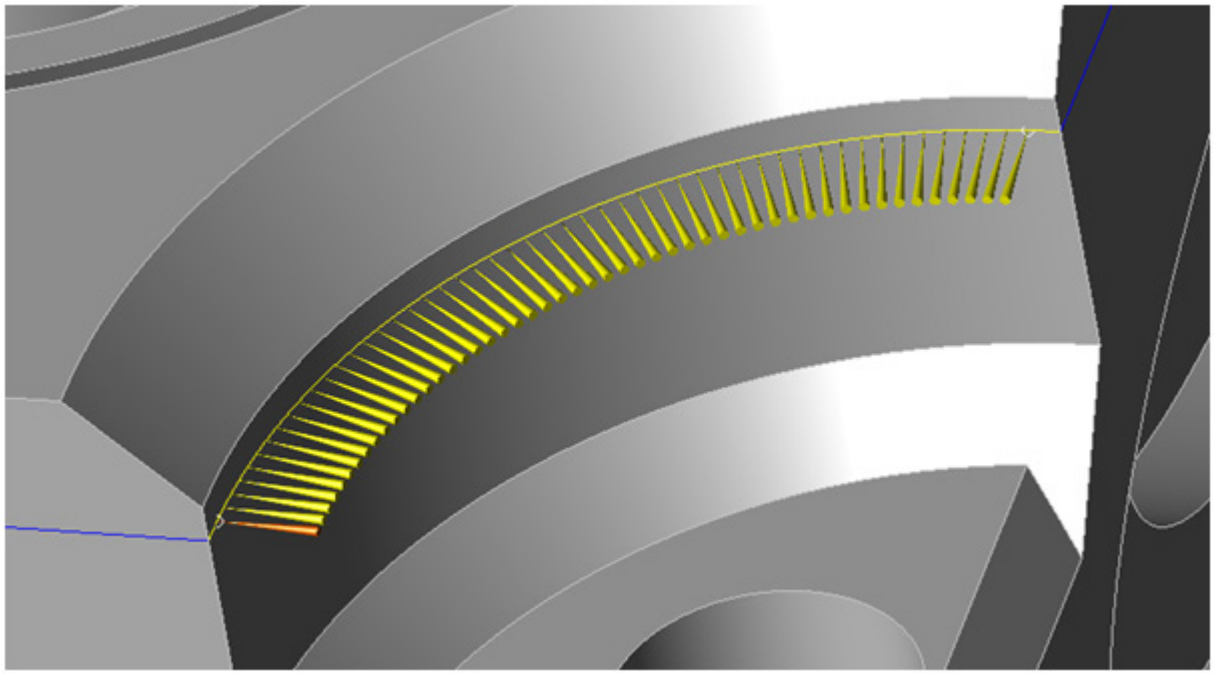


Create an alignment on the part that is being measured (e.g. Renishaw demo block).

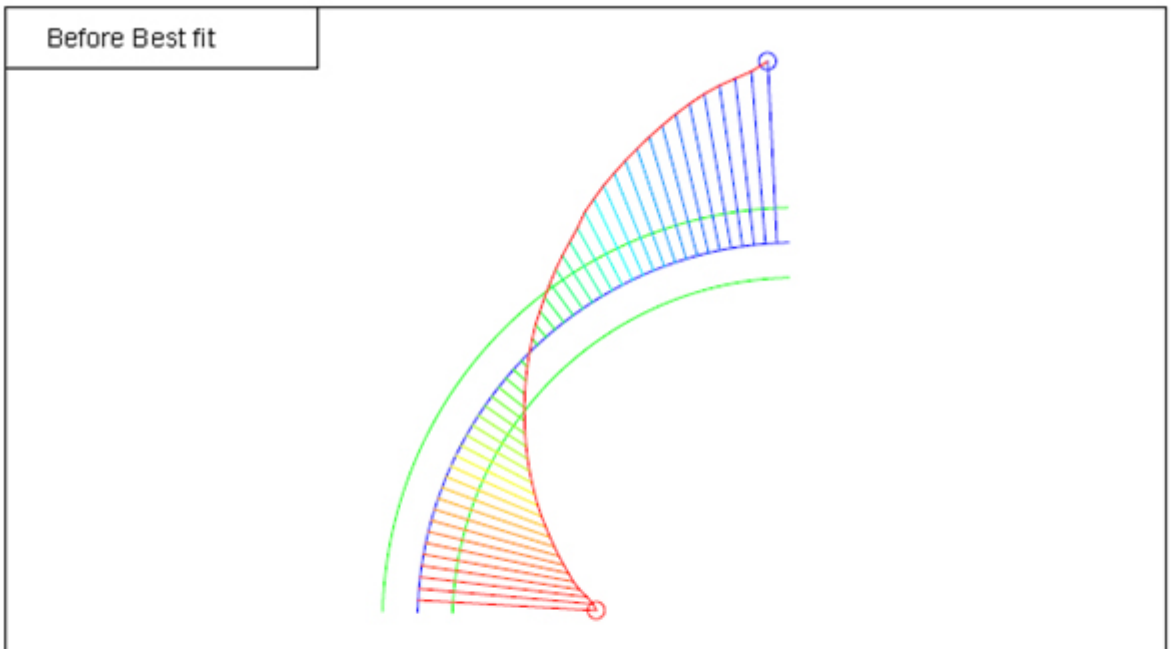
To make the error in actual and nominal more pronounced, rotate the part a slight amount. This will help to see the effect of 'Datum Locate'.

GUIDANCE NOTE: Do not move the part out of alignment so much that it cannot be measured, but enough to see a difference. If there is already a perceptible error, the movement may not be necessary.

Measure a GCURVE similar to the curve shown below, so it can be output as a profile.



In MODUS reporter, plot the curve to show the error. This shows a large amount of error.

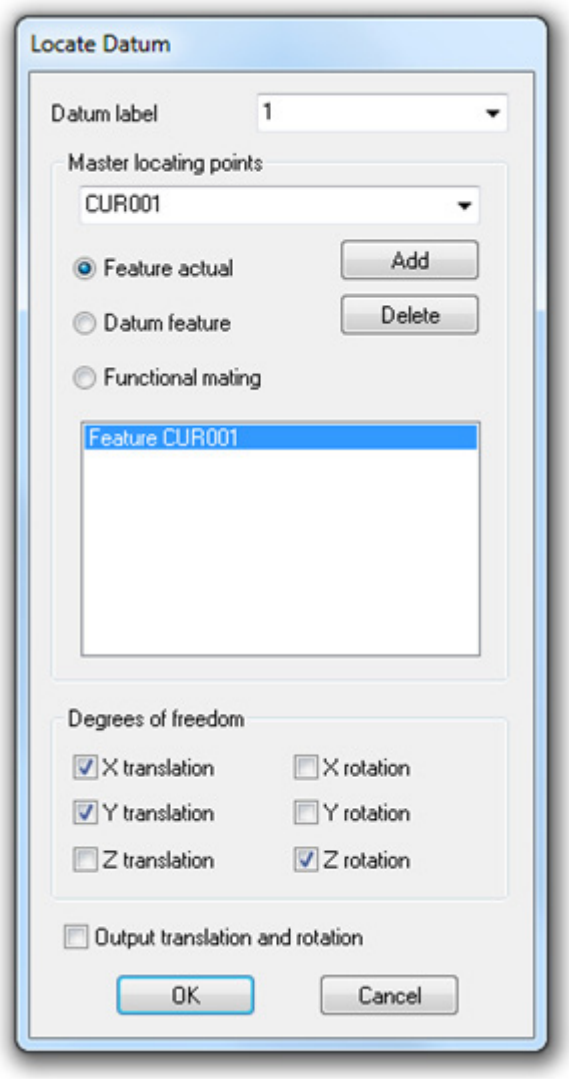


Nom Upr	Nom Lwr	Act Upr	Act Lwr	Upr Tol %	Lwr Tol %	Error
0.1000	-0.1000	0.5112	-0.5188	511.1934	-518.7940	-0.4188

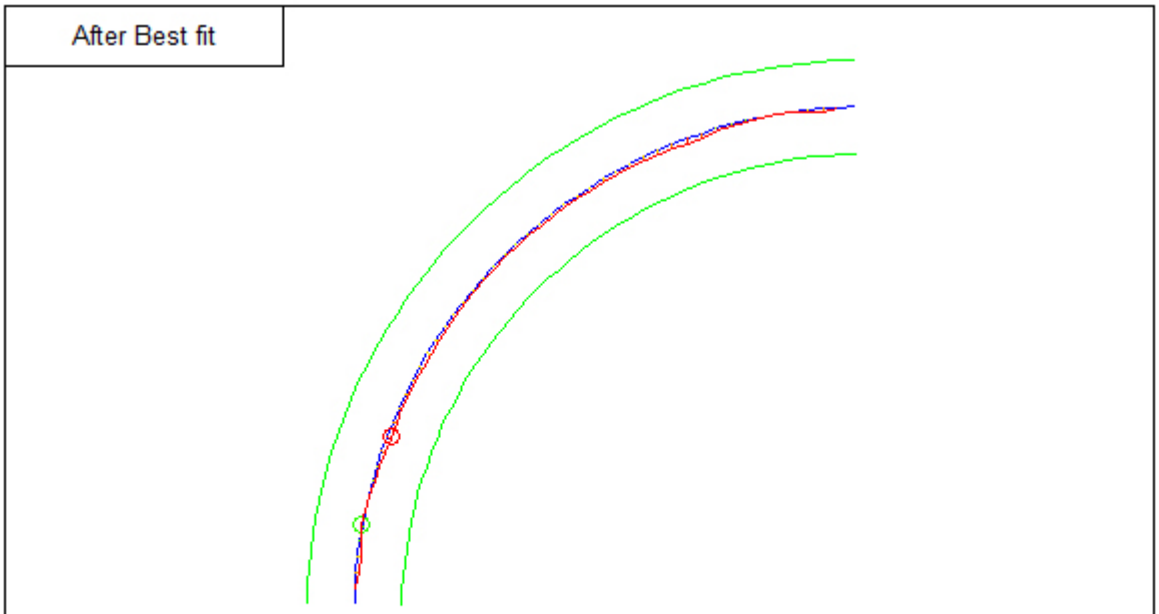
This curve can now be aligned or fitted, using LOCATE from the DATUM menu.

Any fitting requires, as a minimum, an equal number of points as there are degrees of freedom. In the earlier alignment, there were 6 DOF and 6 measured points.

In this example, there are 3 DOF, but only one curve. It may seem that the minimum has not been met. However, since the curve contains more than 3 points, there are more than the minimum required points. This means that there will be an over-constrained condition, which results in a best fit or averaging of the data.



After executing the ‘Locate Datum’ command, output the resulting curve through MODUS and plot the curve in MODUS reporter. There is still a small amount of error, but it is significantly better, and is as good as the set of points can be aligned. This illustrates the technique of best fitting.



Nom Upr	Nom Lwr	Act Upr	Act Lwr	Upr Tol %	Lwr Tol %	Error
0.1000	-0.1000	0.0108	-0.0009	10.7768	-0.8826	0.0000

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